HYDROGEOLOGIC STUDY

OF THE

FRESHWATER AQUIFER

AND

DEEP GEOLOGIC FORMATIONS

SARNIA, ONTARIO

VOLUME 1

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

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SARNIA, ONTARIO

VOLUME I

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EXECUTIVE SUMMARY

This report, in two volumes, describes the results of a hydrogeologic study of the Fresh Water Aquifer and deep geologic formations in the Sarnia, Ontario area. The study was undertaken to assess the extent to which the St. Clair River and a thin sand and gravel aquifer (Fresh Water Aquifer), located at the bedrock surface, have been impacted by past practices of industrial waste disposal to the Detroit River Group of Formations located at 150 to 200 m below bedrock surface.

To fulfill these objectives, reviews of existing information, completion of extensive field drilling, testing and sampling programs and computer modeling of the Fresh Water Aquifer and deep geologic formations were undertaken. The field programs completed in this study included: drilling, testing and installation of fifteen groundwater monitoring wells to the Fresh Water Aquifer; drilling, testing and installation of one 300 m deep borehole to the disposal formation in the Detroit River Group of Formations; and quarterly groundwater sampling and hydraulic head monitoring of a 29 point monitoring well network of the Fresh Water Aquifer and of the deep borehole. The computer modeling included a numerical simulation of groundwater flow in the Fresh Water Aquifer and simulation of waste migration within the disposal zone. The potential size of contaminant plumes that may result from vertical migration through an open abandoned borehole between the disposal zone and the Fresh Water Aquifer was also simulated using a computer model.

The results of this study show that the Fresh Water Aquifer is a thin, discontinuous aquifer located at or near the bedrock surface with an average hydraulic conductivity of 5×10^{-6} m/s. A buried bedrock valley of depth 60-80 m below ground surface and 30-40 m below surrounding bedrock is located about 500-1000 m east of the current channel of the St. Clair River. The Fresh Water Aquifer has a higher hydraulic conductivity of about 1×10^{-4} m/s within the bedrock valley due to the presence of alluvial sands and silts. The Fresh Water Aquifer is generally overlain by 30-70 m of low permeability clay till, however, below the St. Clair River the thickness of confining till in places may be a thin as 3 m.

Groundwater flow within the Fresh Water Aquifer toward the bedrock valley averages 0.57 m^3/a per unit aquifer width. Within the bedrock valley some flow is directed down to deeper geologic formations and some of the flow is discharged to the St. Clair River. No groundwater flows under the St. Clair River within the Fresh Water Aquifer to the U.S.

Phenol contamination of the Fresh Water Aquifer by injected industrial waste is evident on the Esso Petroleum Canada property near the St. Clair River and below the St. Clair River in the area of the CN railway tunnel. Loading to the St. Clair River from this 800 m by 600 m contaminated zone is calculated at 5.2 g/d which, given the volume of flow in the St. Clair River, is rapidly reduced to below detection levels. Chloride contaminant loading to the River from the same area is calculated at 50 kg/d. Cleanup of this contaminated zone by groundwater pumping is potentially dangerous and may introduce more contamination to the fresh water aquifer.

It is recognized that some undetected contaminant plumes may exist in the vicinity of disposal wells due to waste migration up abandoned or poorly completed boreholes. Assuming such plumes did exist adjacent to the St. Clair River the total potential phenol loading to the River is estimated at 25 g/d. This would result in an increase in phenol concentration in the River of 0.057 ng/L which is much less than the minimum detection limit of 1 ug/L. This potential phenol loading is small in comparison to other municipal/industrial point source loadings to the St. Clair River in the Sarnia area.

Industrial waste, characterized by phenol (30,000 - 40,000 ug/L), volatile organics (e.g., benzene, toluene, etc. - 200-5800 ug/L) and naphthalenes (50 - 829 ug/L) is restricted to a narrow 11 m zone of residual contamination between 185.9 and 196.6 m depth in the upper section of the Lucas dolomite. Vertical migration of this waste through the pore space of the overlying and underlying rocks has been negligible and measured hydraulic heads show fluid flow

in the adjacent rocks is now towards the zone of residual contamination. This study suggests that there is a relatively active flow system within the disposal formation today and that understanding the fate of the 8,000,000 m^3 of industrial waste disposed to the Detroit River Group will require knowledge of the current rates and directions of flow within the disposal zone.

The hydraulic head within the zone of residual contamination is now 14-15 m below that in the Fresh Water Aquifer and 8 m below the level of the St. Clair River. Therefore current potential flow directions are from the Fresh Water Aquifer and St. Clair River to the disposal zone.

The chemical composition of the industrial waste collected from the Lucas dolomite does not contain chlorinated volatile organics such as perchloroethylene and carbon tetrachloride and therefore is dissimilar to the St. Clair River "blobs" detected in 1985. This chemical dissimilarity and the hydraulic head relations described above indicate that the St. Clair River "blobs" were not related to upward movement of industrial waste from the Detroit River Group of Formations to the St. Clair River.

A significant finding of this study was the occurrence of high hydraulic conductivity limestone layers in the Hamilton Group of Formations at 74 and 123 m depth that likely contain industrial waste at phenol concentrations of 6000 - 10,000 ug/L and hydraulic heads due to gas pressure that are above those in the Fresh Water Aquifer. The 2 m thick limestone layer at 74 m depth is of particular concern to this study because groundwater from this horizon likely discharges to the Fresh Water Aquifer within the bedrock valley and this horizon flowed industrial waste in 1967 and 1969 at rates of 10 - 238 L/min. The extent of contamination in this and the 123 m depth horizon is not known but is likely significant as the only two monitoring wells in these horizons (from this and an earlier study) detected industrial waste. This waste was likely introduced to these limestone horizons from improperly completed disposal, cavern or abandoned wells.

Recommendations for further work are developed in this study to further define the hydrogeologic and contaminant migration potential of the Fresh Water Aquifer and deep geologic formations. Ongoing water level monitoring and groundwater quality sampling is recommended in the established Fresh Water Aquifer monitoring well network and the deep borehole to the disposal formation. Additional boreholes are recommended to the limestone units at 74 and 123 m depth to define the levels and extent of contamination and the groundwater flow rates and directions. Two additional boreholes to the disposal horizon in the Detroit River Group are recommended to aid in determining the fate of the 8,000,000 m^3 of injected industrial waste.

7. CONCLUSIONS AND RECOMMENDATIONS

7.1 CONCLUSIONS

Based upon the work described in this report and in consideration of the study objectives outlined in Section 1.2 we conclude the following for the Fresh Water Aquifer and deep geologic formations.

7.1.1 Fresh Water Aquifer

- The Fresh Water Aquifer is a thin (2 m average thickness) discontinuous sand and gravel and fractured shale aquifer that generally follows the bedrock surface with average hydraulic conductivity of 5×10^{-6} m/s.

- A buried bedrock valley of depth 60 - 80 m below ground surface subparallels the St. Clair River and is located about 500 to 1000 m east of the current channel. The bottom of the bedrock valley is about 30-40 m below the surrounding bedrock. Lower sections of the bedrock valley are infilled with reworked till and alluvial deposits and the Fresh Water Aquifer within the bedrock valley is permeable with an average hydraulic conductivity of 1×10^{-4} m/s.

- The Fresh Water Aquifer is generally confined by 30-70 m of low hydraulic conductivity (10^{-10} m/s) clay till. Below the St. Clair River the clay till thins in places to as little as three meters and more permeable alluvial deposits are present.

- Groundwater flow within the Fresh Water Aquifer is northwesterly across the study area and generally discharges to the St. Clair River. Flow on the U.S. side of the River is a mirror image to that on the Canadian side. Groundwater fluxes toward the bedrock

valley on the Canadian side average 0.57 m^3/a per unit Aquifer width. Hydraulic heads measured in monitoring wells completed within or proximate to the bedrock valley indicate that some of the flow entering the bedrock valley discharges to depth, likely to deeper geologic formations.

- Monitoring well studies show that industrial waste and brine contamination of the Fresh Water Aquifer is limited to an 800 m x 600 m area generally on Esso Petroleum Canada property and below the St. Clair River, in the vicinity of the CN tunnel, EPC wells RW-1, AQ1 and AQ11 and EPC disposal well DW3. Neglecting flow losses to depth to the bedrock valley, the phenol loading to the St. Clair River from this contamination is estimated at 5.2 g/d which given the flow rate within the River would be rapidly reduced to below detection levels. Similar calculations for chloride indicate a chloride loading to the St. Clair River from measured sources of about 50 kg/d.

- Assuming some undetected phenol contaminate plumes may exist within the Fresh Water Aquifer in the vicinity of the St. Clair River and existing disposal wells due to fluid flow up an abandoned borehole, a worst case loading estimate to the St. Clair River can also be determined. This potential loading is calculated at 25 g/d which with mixing in the River would result in an increase in phenol concentration of .057 ng/L which is much less than the detection limit for phenol at 1 ug/L. This potential phenol loading is small in comparison to identified municipal/industrial point sources.

- Additional loading of industrial and brine waste to the Fresh Water Aquifer within the bedrock valley is possible through discharge of contaminated formation waters located at 74 m depth within the Widder Formation of the Hamilton Group.

7.1.2 Deep Geologic Formations

- Groundwater within the deep geologic formations is typically Na-Cl type saline waters or brines with density of 1.03 to 1.13 and increased salinity with depth. The density and total dissolved solids content increases dramatically below a depth of about 220 m in the Lucas Formation.

- Industrial waste characterized by phenol (30,000 -40,000 ug/L), benzene, toluene, xylenes, ethyl- and methyl-benzenes (200 - 5800 ug/L) and naphthalenes and methylnaphthalenes (50 - 829 ug/L) is restricted to a narrow 11 m interval between 185.7 and 196.6 m depth within the upper section of the Lucas Formation dolomite. Vertical migration of this waste both upward and downward through the pore space of the overlying and underlying formations has been restricted to about 10 m.

- Current hydraulic conductivity and hydraulic head conditions provide hydraulic isolation of the zone of residual contamination centred at 192 m and restrict vertical flow from this zone. The hydraulic head within the zone of residual contamination is stable at an equivalent water level of 168.39 m AMSL. Considering density effects this level is about 14-15 m below the fluid level in the Fresh Water Aquifer at the same location and about 8 m below the level of the St. Clair River in the Sarnia area. Therefore the current potential fluid flow directions are from the Fresh Water Aquifer and the St. Clair River toward the zone of residual contamination in the Lucas Formation.

- The chemical composition of the industrial waste from the Lucas Formation dolomite does not contain chlorinated volatile organics such as perchloroethylene and carbon tetrachloride and therefore is dissimilar to the St. Clair River "blobs" detected in 1985. This chemical dissimilarity and the current hydraulic head

conditions indicates that the occurrence of the St. Clair River "blobs" were not related to upward movement of industrial waste from the Detroit River Group to the St. Clair River.

- Lateral flow within the disposal zone is likely significant and the fate of the 8,000,000 m^3 of waste disposed to the Detroit River Group can only be determined by understanding the current flow rates and directions within the disposal zone. There is insufficient data to reliably determine this.

- High permeability limestone layers of 2-3 m thickness at 74 and 123 m depth in the Hamilton Group in the Sarnia area likely contain industrial waste with phenol concentrations of 6000 - 12,000 ug/L. Hydraulic heads in these zones are above the level of the head in the Fresh Water Aquifer. The zone at 74 m depth is exposed within the deeper sections of the bedrock valley and flow is likely from the formation to the Fresh Water Aquifer in the bedrock valley. The level and extent of contamination within this horizon is not well known. The industrial waste was likely introduced to these horizons through improperly completed disposal wells, cavern wells or abandoned wells.

7.2 RECOMMENDATIONS

Based on the results and conclusions described in this study we recommend the following activities to more clearly define the hydrogeology of the Fresh Water Aquifer and deep geologic formations.

- Monitoring of water levels in the MOE and EC monitoring well network on a semi-annual basis.

- Water quality sampling of all monitoring wells in the MOE and EC monitoring well network on a semi-annual basis.

- Analyses of water samples for indicator parameters of contamination such as phenols and major ion chemistry.

- Sampling of monitoring wells in the MOE and EC monitoring well network for environmental isotopes ^{18}O, ^{2}H, and ^{3}H. Several of the earlier samples contain drill water contamination.

- Pressure monitoring of borehole MDMW-1 on a semi-annual basis to determine the long term formation pressures in the deep borehole. Many intervals within the Hamilton Group have yet to reach equilibrium pressure conditions.

- Water quality sampling of the sampled intervals in borehole MDMW-1 on a semi-annual basis. Analyses of water samples for phenols, major ion chemistry, volatile organics and acid extractable organics. Stable and reproducible water quality analyses have not yet been collected from the majority of intervals within the borehole.

- The potential for contamination of the Fresh Water Aquifer from industrial waste contamination in the 74 m and 123 m depth limestone layers in the Hamilton Group should be investigated. This potential is greatest from the 74 m depth horizon which likely flows into the Fresh Water Aquifer in the deeper sections of the bedrock valley. Drilling, testing, casing installation and monitoring of four new boreholes to the Hamilton Group are recommended. Two boreholes should be drilled within or proximate to the bedrock valley and two boreholes should be drilled east of the bedrock valley.

- To understand the fate of the industrial waste disposed to the Detroit River Group, two deep boreholes completed to the disposal formation are required to quantify the current directions and rates of groundwater movement.